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A SOLID STATE POSITION SENSITIVE X-RAY DETECTOR FOR THE LCLS :
A PROPOSAL FOR CATEGORY C. (LETTER OF INTENT)

This proposal describes a detector system which fulfils the requirements for the Structural Study on Single Particles and Biomolecules (Category A).

The LCSL will produce X-rays in bunches, with a frequency of 120 Hz. A detector will receive the diffracted X-rays in short flashes with a repetition period of 8.3 msec. The read-out time will be long between the two bunches of X-rays. This the inverted case as compared to the usual protein crystallography.

The detector we are proposing is based on the direct conversion of X-.ray into electric charges. This is achieved by the absorption of X-rays in a photoconductor. Although this technology seems evident, it is still not very common. And, despite the photoelectric effect as such being well known, the technology has only been used in the medical market since recent time. The so-called flat panel detectors are now starting to be accepted (FDA-approval) in the medical field. Nevertheless, here one has to differentiate between the “indirect” and the “direct” conversion. Indirect conversion makes use of a phosphor and an array of photodiodes. The result is an unavoidable blurring of the X-ray image. In addition, the photodiodes show a strong dark – or leakage – current at normal temperature. For these reasons, the indirect conversion method has not been pursued by Marresearch.
Direct conversion has important advantages in X-ray diffraction applications , such as protein crystallography.
Marresearch has been collaborating with an American partner (Hologic Inc.) on the development of a flat panel detector for protein crystallography. A detector developed for Medical use has been further developed and improved for this special field of application. Significant modifications were necessary – especially concerning the signal-to-noise ratio. We managed to reduce the read-out noise by a factor of 10, as compared to the original medical version.
This medical flat panel detector is based on a so-called TFT read-out system. Although this system enables read-out times in the order of 0.5 seconds, it is difficult to shorten this time by a factor of 10, which is needed for the 120Hz frequency required for the FEL pulse rate.

We propose a different concept which is especially suited for the LCLS case with very short exposure flashes followed by a short read-out time of 8 msec.

The Direct Conversion Detector

The detection principle is the direct conversion of X-rays into charges. The most well known photoconductor is Selenium. Other photoconductors, PbI_2, HgI_2, CdZnTe, are known to have significant hindrances (e.g. high dark current).
Nevertheless, Selenium also has a disadvantage, namely the high energy which is required for the production of an electron-hole pair (ehp): Typically, 80eV are needed per ehp, resulting in a signal of 150e^- per 12keV X-ray$^-$. However, the design of very low noise amplifiers has made it possible to achieve excellent signal-to-noise ratios at low energy X-rays (8 to 12keV).
A better way of achieving low signal-to-noise ratios is to improve the signal output of the detector itself. It has been shown in laboratory experiments that avalanche multiplication of the number of charges per X-ray is feasible. These simple pioneering experiments showed the way to more sophisticated systems with controlled amplification.
Simulations show that a 10-fold signal increase is feasible. The technology for this system is readily available.
Together with low-noise amplifiers, a single-photon-counting system at 8 or 12 keV is feasible.
The basic principle of such a detector system is shown in Figures 1. and 2.
The basic system is a photoconduction layer consisting of an absorption layer for the conversion of X-rays into primary charges, followed by an amplification layer.
The amplified charges are collected by pixel electrodes. The pixel capacitors are sensed in a non-destructive way by one single transistor per pixel. Multiple read-out of the charges is feasible, but most likely not necessary. Pixels along a column are switched to a row of amplifiers. Both, left and right sides of the detector are read out simultaneously. The analogue-to-digital conversion of all segments also takes place simultaneously.
Fast electronic components and modern integration technology makes fast read-out systems feasible.
The use of large scale integration circuit techniques make a high production yield possible.

The combination of

- A photoconductor layer (a-Se) for conversion of X-rays and amplification of the signal
- and low noise amplifiers (a single transistor per pixel)
- with a parallel data-conversion system

makes such a detector well suited for a fast and extremely low noise data collection system.

With this letter of intent, it is suggested to first build a small size detector (50 mm x 50 mm) with 512 x 512 pixels and 100 µm x 100 µm size. A system with these dimensions can be built on a single wafer. Later in time, a large tiled or untiled system can be envisaged.

Figure 1.

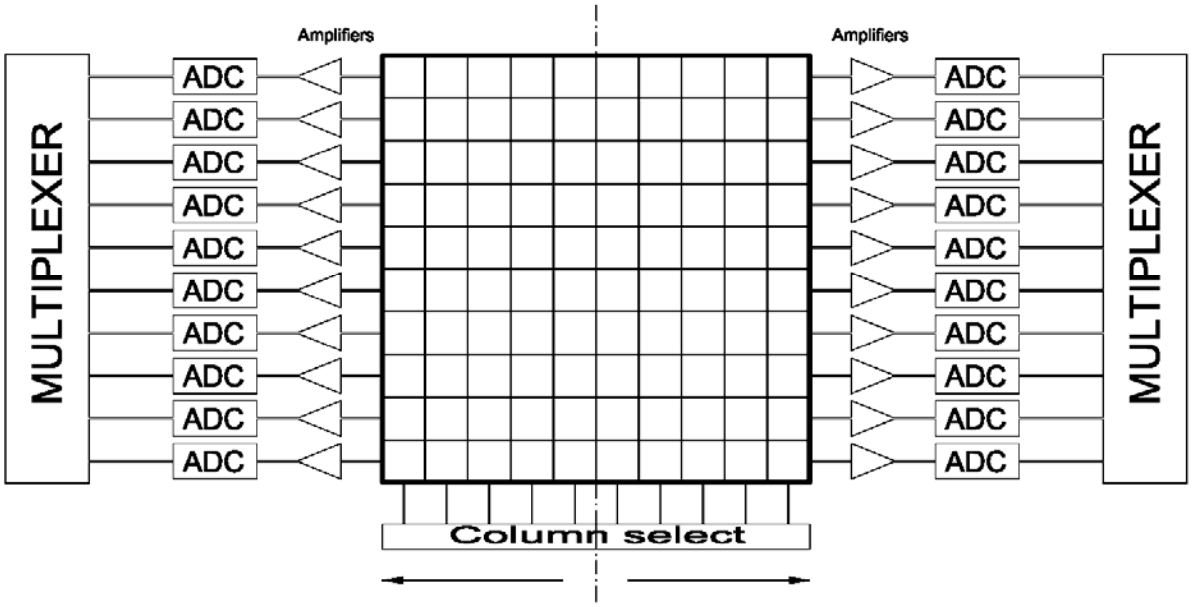
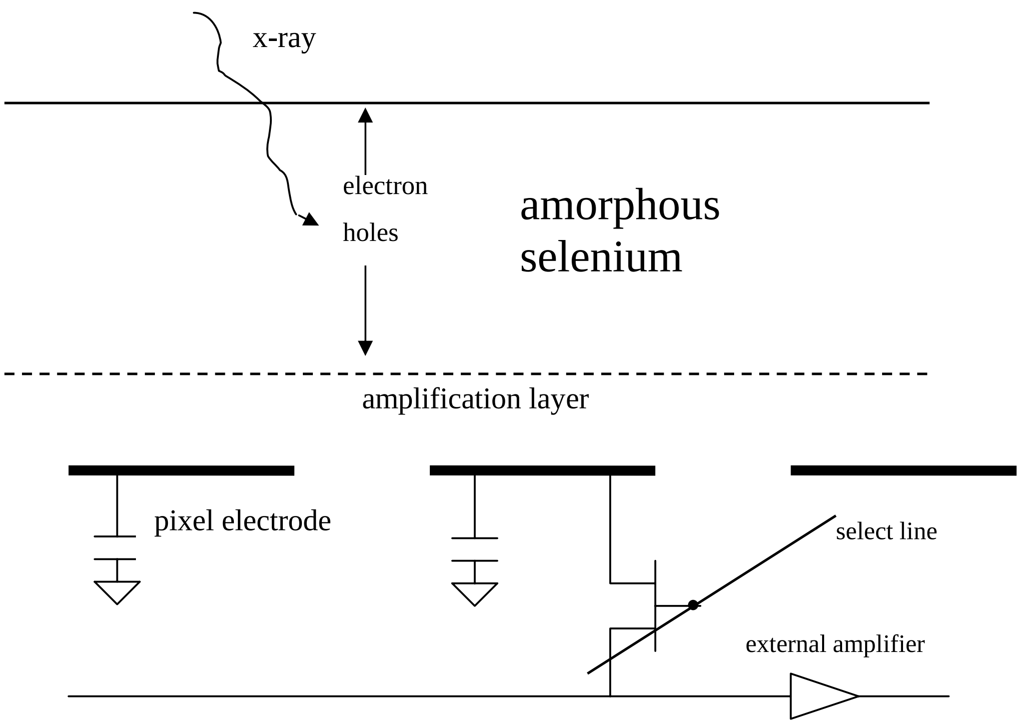


Figure 2.



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